



US006580259B2

(12) **United States Patent**
Liu et al.

(10) **Patent No.:** **US 6,580,259 B2**
(45) **Date of Patent:** **Jun. 17, 2003**

(54) **HIGH EFFICIENCY AC-DC CONVERTER WITH POWER FACTOR CORRECTOR**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/040,841**

(22) Filed: **Jan. 7, 2002**

(65) **Prior Publication Data**

US 2002/0110012 A1 Aug. 15, 2002

Related U.S. Application Data

(60) Provisional application No. 60/262,186, filed on Jan. 17, 2001.

(51) **Int. Cl.**⁷ **G05F 1/40**

(52) **U.S. Cl.** **323/282; 323/222**

(58) **Field of Search** **323/222, 223, 323/224, 273, 266, 282; 363/59**

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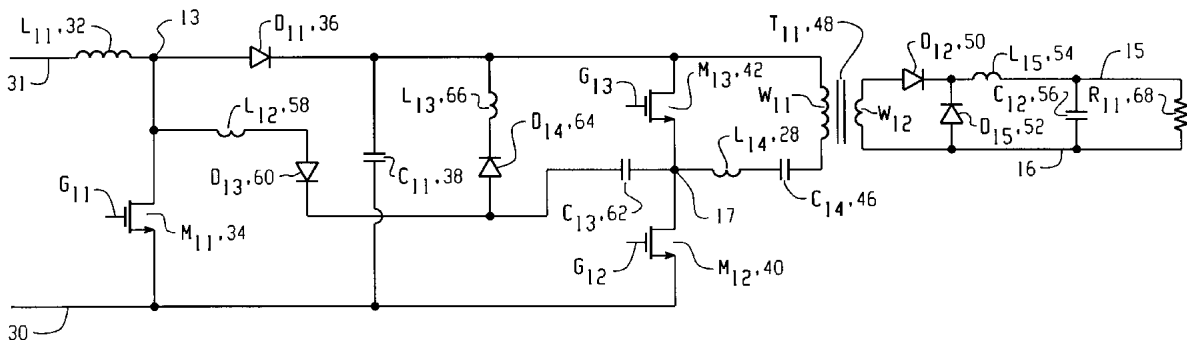
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(57) **ABSTRACT**

An AC/DC power converter includes a pair of input terminals, a boost unit, a DC/DC converter, a coupler chain, and a discharge chain. The pair of input terminals connect to a pulsating DC source. The boost unit is coupled to the input terminals and generates a voltage higher than the voltage at the input terminals. The DC/DC converter couples to the boost unit and includes a set of series switches coupled to the primary side of a transformer through a series inductor and capacitor. The DC/DC converter further includes a secondary winding coupled to the transformer and coupled to a rectifier and filter configuration. The coupler chain couples the boost unit to the DC/DC converter. The discharge chain couples the coupler chain to the high voltage source generated by the boost unit. Control pulses synchronize the series switches so that a resonant current flows in the coupler chain and the discharge chain such that the switches can be turned on and off while voltages across the switches are substantially zero.

18 Claims, 6 Drawing Sheets



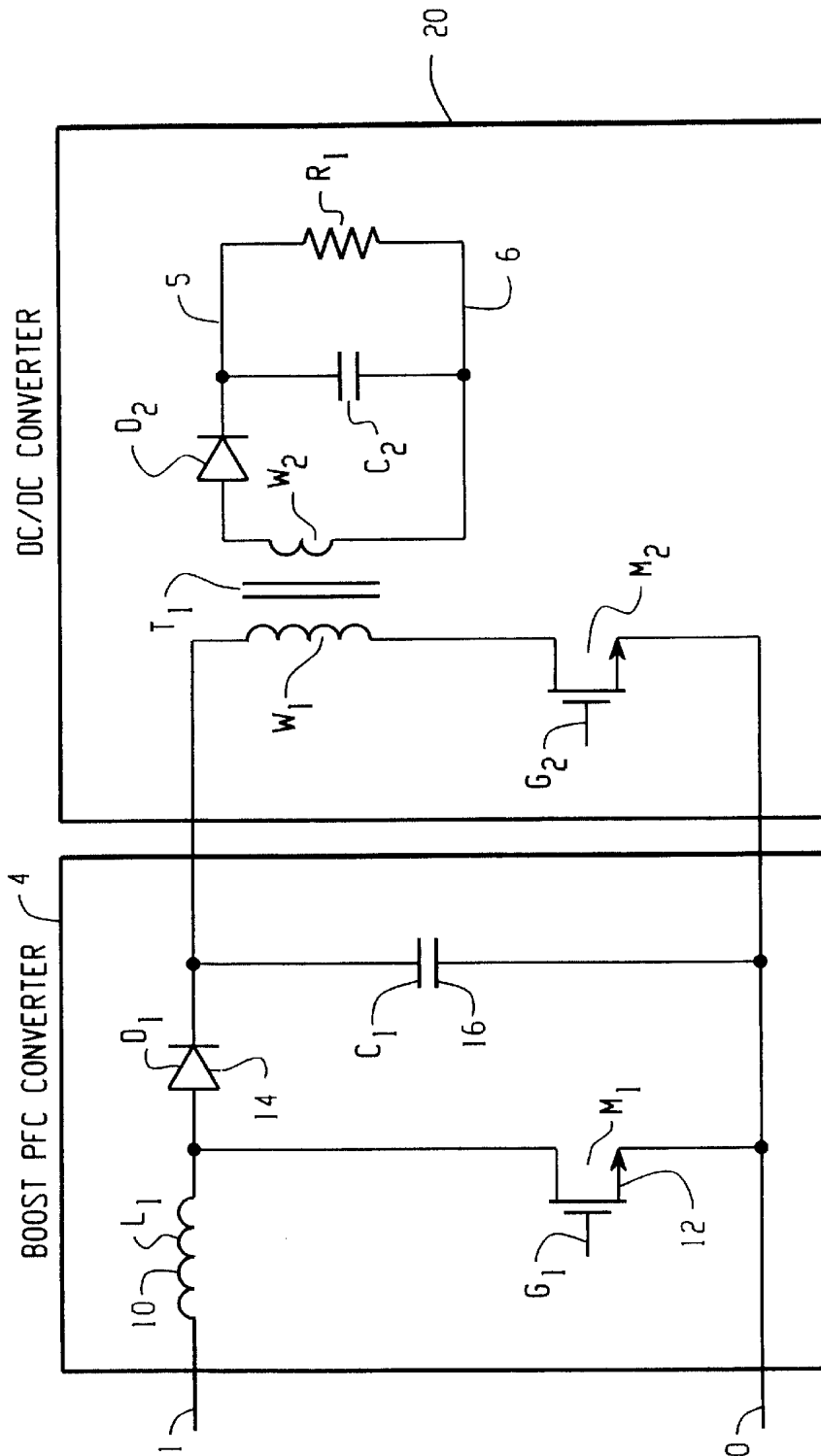


Fig. 1
PRIOR ART

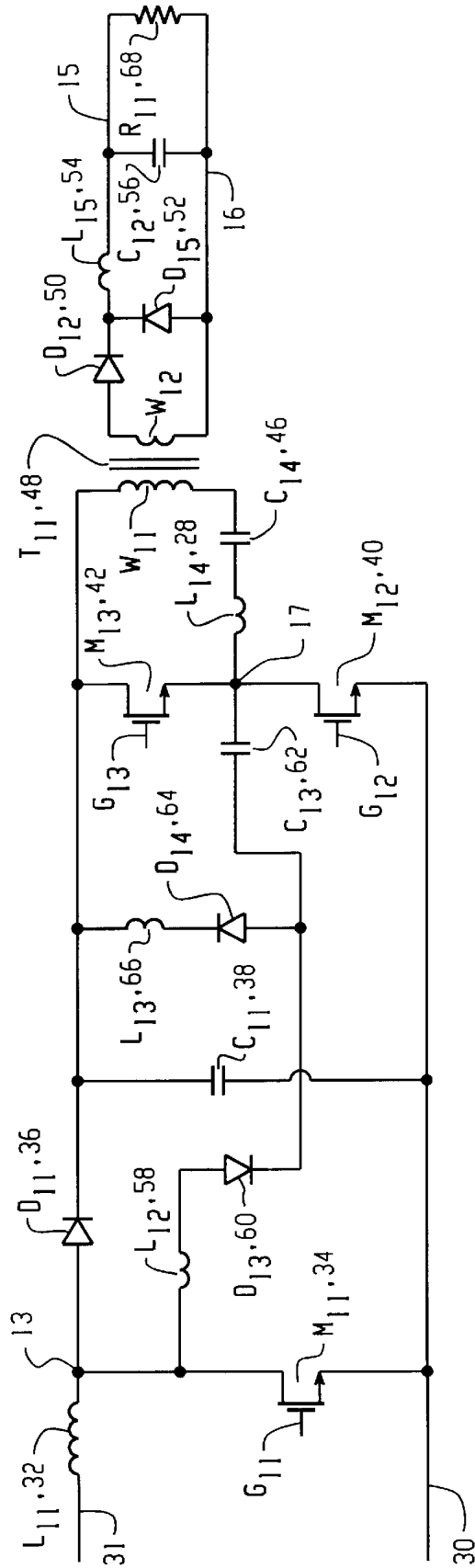
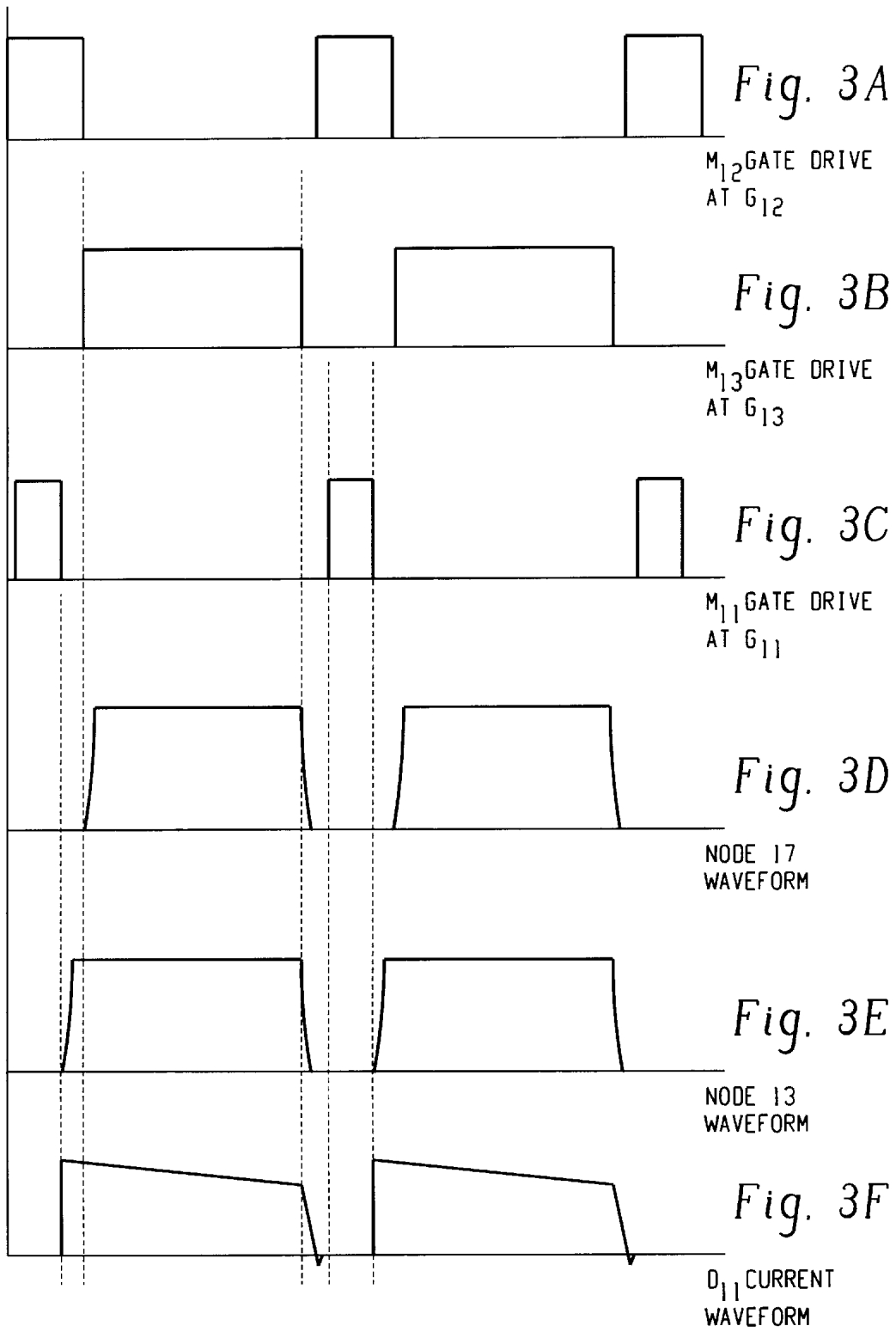


Fig. 2



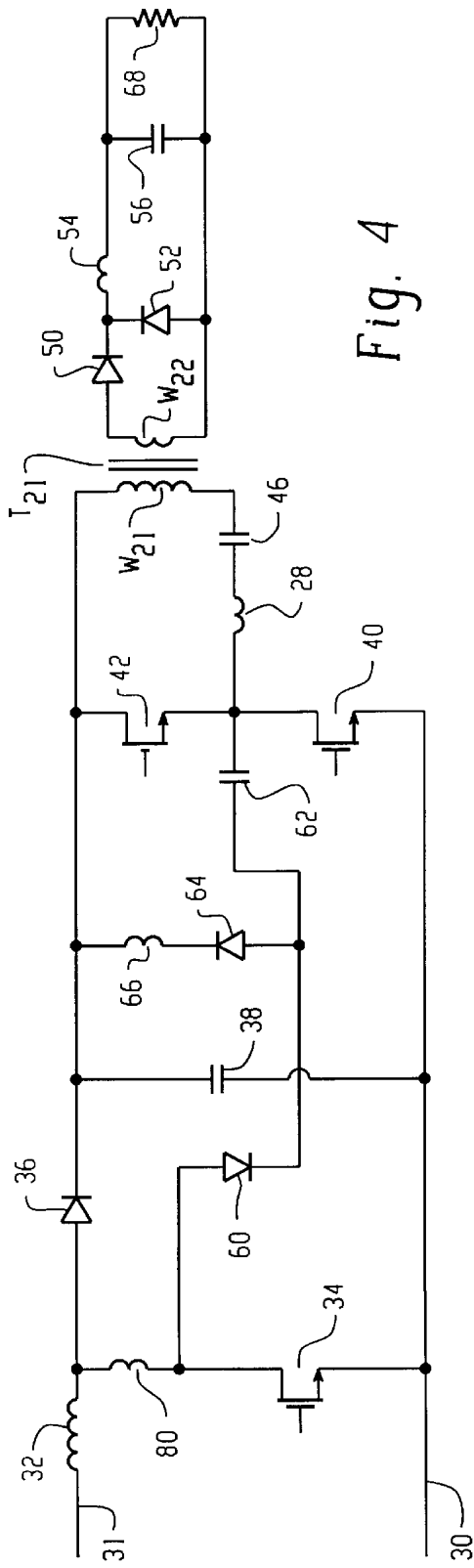


Fig. 4

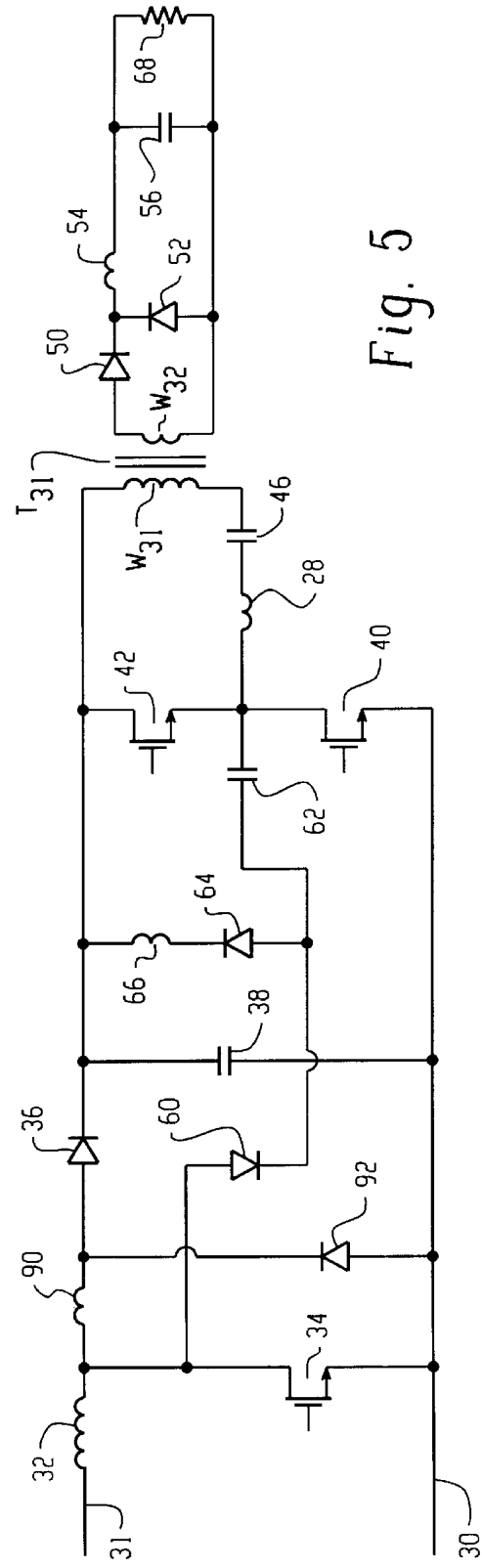


Fig. 5

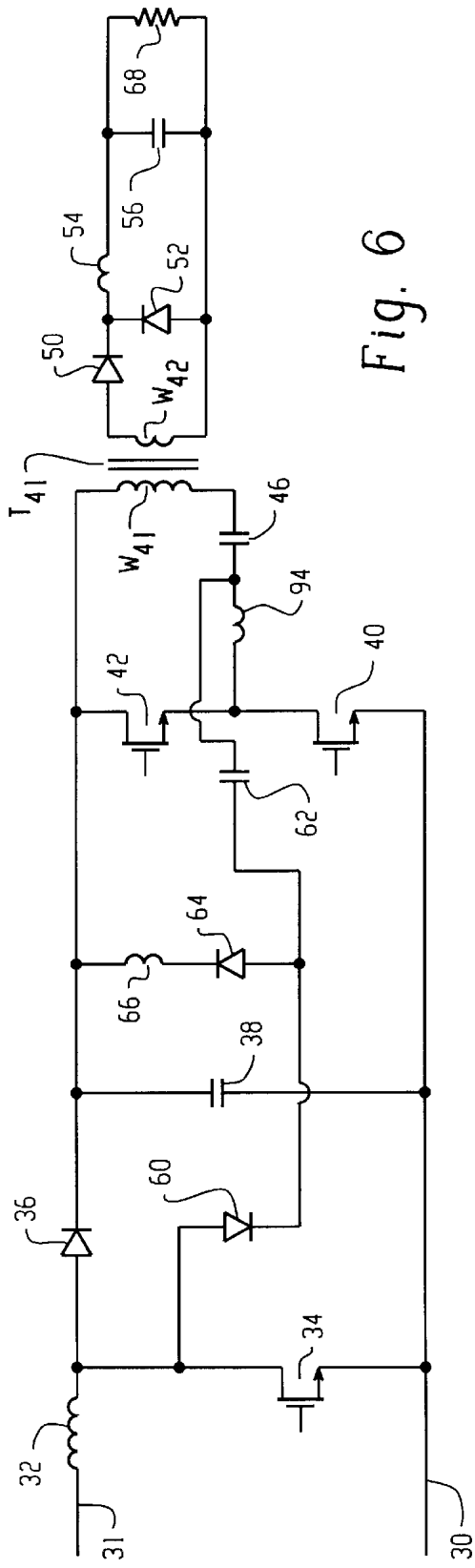


Fig. 6

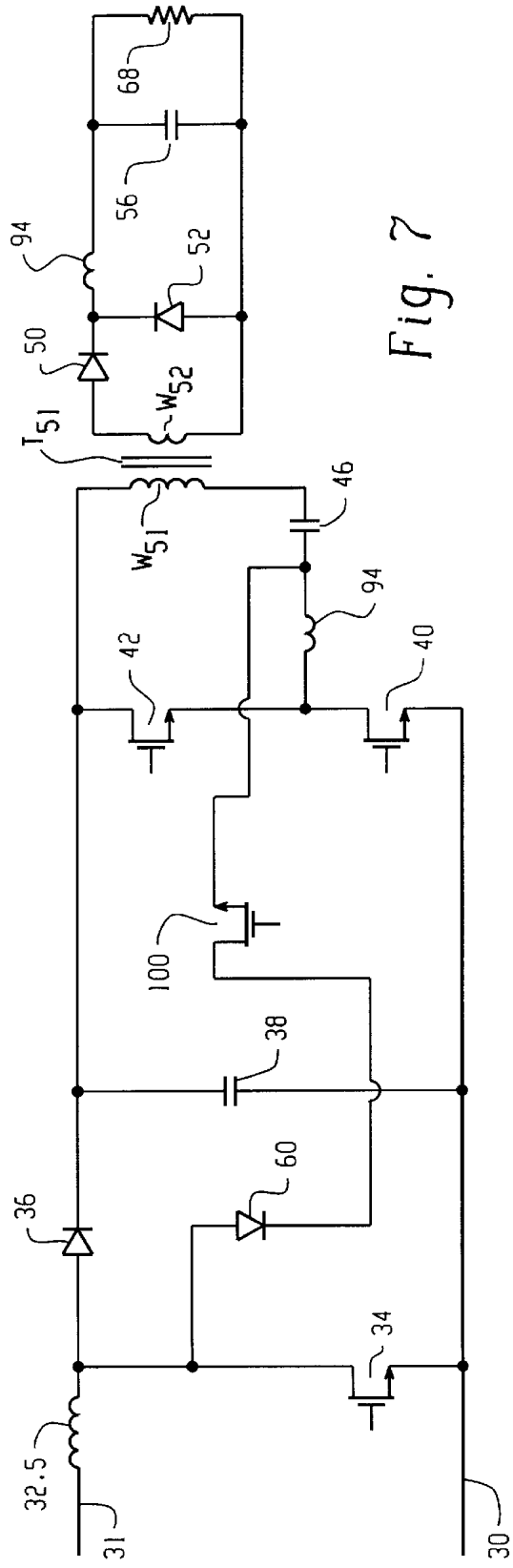
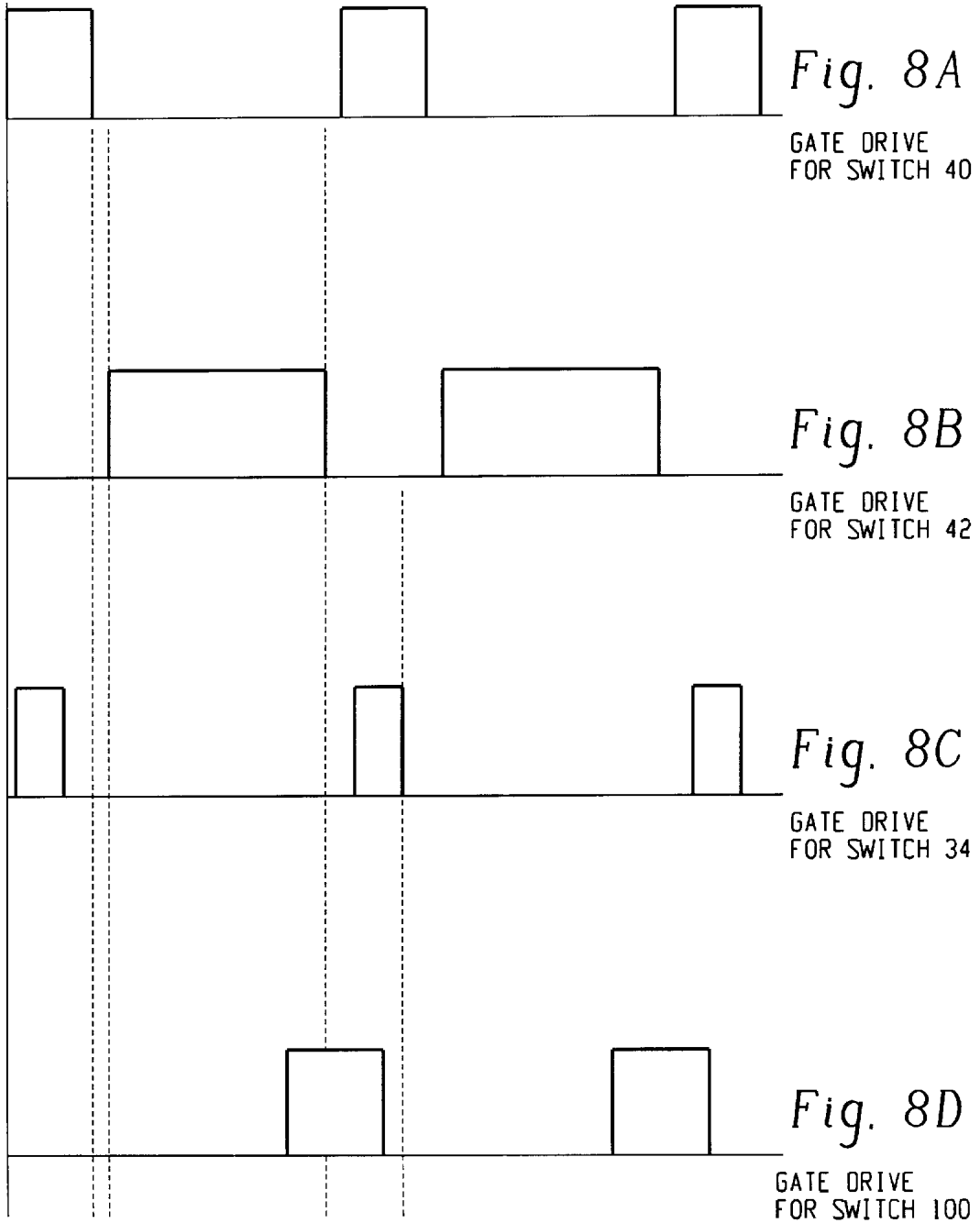


Fig. 7



HIGH EFFICIENCY AC-DC CONVERTER WITH POWER FACTOR CORRECTOR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from and is related to U.S. Provisional Application No. 60/262,186, filed on Jan. 17, 2001, and entitled "A High Efficiency AC-DC Converter With Power Factor Corrector." U.S. Provisional Application No. 60/262,186, including the entire written description and drawing figures, is hereby incorporated by reference into the present application.

BACKGROUND

1. Field of the Invention

This invention relates to the field of power converters. Particularly, this invention relates to the field of AC to DC converters with Power Factor Correction (PFC).

2. Description of the Related Art

AC/DC converters need power factor correction in order to fulfill international standards of low input harmonic current content. A front-end boost PFC converter is one way to obtain good input harmonic current to meet these international standards. Generally, another DC/DC converter is cascaded from the front-end boost PFC converter to provide a steady output voltage.

FIG. 1 shows a typical configuration of an AC-DC converter with power factor correction. Rectified AC is fed to input terminals of a boost converter **4** at nodes **0** and **1**. The boost converter **4** includes an inductor L_1 **10**, MOSFET switch M_1 **12**, diode D_1 **14** and capacitor C_1 **16**. A series of Pulse Width Modulated (PWM) voltage pulses are fed to the gate terminal G_1 of the MOSFET switch **12**. The pulse width of the voltage pulses are programmed to make the input current follow the shape of the input sinusoidal voltage and build up a voltage across capacitor **16**. A DC/DC converter **20** converts the voltage across capacitor **16** to a regulated DC voltage across output nodes **5** and **6**.

A problem in boost converters is the reverse current of the diode **14** when the switch **12** turns on. When the switch **12** turns on, it draws reverse recovery current through the diode **14** and turns the switch **12** off abruptly to block the reverse voltage equal to the output voltage of the boost PFC converter **4**. The output voltage is always higher than the peak of the rectified AC and very often is close to 400V. This high output voltage causes a large amount of switching loss when the diode **14** is turned off. This switching loss increases with frequency. However, high switching frequency is often required to reduce the size and weight of the passive components. Thus PFC boost converter **4** generally are lossy circuits due to the high switching frequencies of the circuit. In fact, the switching loss is associated with every switch in the boost converter **4** and every switch in the DC/DC converter **20**.

Previous work uses various techniques to reduce switching losses. In U.S. Pat. No. 5,313,382, Farrington discloses a boost converter with an auxiliary switch and a resonant network to achieve reduced voltage stress at a main power switch during turn on. The boost converter also enables a soft turn off of the boost rectifier. The auxiliary switch of the boost converter is turned on without reduced voltage condition, but it has a zero current condition. In U.S. Pat. No. 5,633,579, Kim discloses a boost converter with a stress energy reproducing snubber circuit in order to reduce the stress energy of the boost rectifier during turn off. The

snubber circuit reduces the voltage stress on a main switch of the boost converter during turn on. In U.S. Pat. No. 5,748,457, Poon discloses a DC/DC converter which reduces voltage stress by means of zero voltage switching, but it has no boosting and power factor correction effect.

In addition to soft switching, another problem with PFC converters is control of the switching. Some prior art techniques attempt to integrate the PFC converter and the DC/DC converter. Most of these prior art techniques include converters with fewer degrees of freedom which results in restrictions to operate the converters in certain modes, such as the discontinuous mode. These restrictions prevent maximized utilization of all the components.

SUMMARY OF THE INVENTION

A power converter includes a pair of input terminals, a boost unit, a DC/DC converter, a coupler chain, and a discharge chain. The pair of input terminals connect to a pulsating DC source. The boost unit is coupled to the input terminals and generates a voltage higher than the voltage at the input terminals. The DC/DC converter couples to the boost unit and includes a set of series switches coupled to the primary side of a transformer through a series inductor and capacitor. The DC/DC converter further includes a secondary winding coupled to the transformer and coupled to a rectifier and filter configuration. The coupler chain couples the boost unit to the DC/DC converter. The discharge chain couples the coupler chain to the high voltage source generated by the boost unit. Control pulses synchronize the series switches so that a resonant current flows in the coupler chain and the discharge chain such that the switches can be turned on and off while voltages across the switches are substantially zero.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 (Prior Art) shows a typical configuration of an AC-DC converter with power factor correction;

FIG. 2 shows a circuit comprising a first embodiment of the present invention;

FIGS. 3A to 3F show graphs of voltage and current during operation of the circuit of FIG. 2;

FIG. 4 shows a circuit comprising a second embodiment of the present invention;

FIG. 5 shows a circuit comprising a third embodiment of the present invention;

FIG. 6 shows a circuit comprising a fourth embodiment of the present invention;

FIG. 7 shows a circuit comprising a fifth embodiment of the present invention; and

FIGS. 8A to 8D show graphs of the driving waveforms for the switches of the circuit of FIG. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With respect to the drawing figures, a circuit comprising a first embodiment of the present invention is shown in FIG. 2. The invention includes various interconnected parts that define a plurality of devices that can function together. The circuit includes a boost converter, a DC/DC converter, a coupler chain, a discharging chain, and a soft switch inductor **28**. The boost converter includes an inductor **32**, a MOSFET switch **34**, a diode **36** and a capacitor **38**. The DC/DC converter includes MOSFET switches **40** and **42**, a capacitor **46**. A transformer **48** in the DC/DC converter,

having windings W_{11} and W_{12} , couples the switches **40** and **42** to diodes **50** and **52** which are coupled to an inductor **54** and a capacitor **56**. The resistance **68** is the load of the converter. The coupler chain includes an inductor **58**, a diode **60** and a capacitor **62**. The discharge chain includes a diode **64** and an inductor **66**.

Input terminals **30** and **31** are coupled to a rectified AC source. The input terminals **30** and **31** feed the boost converter. A series of Pulse Width Modulated (PWM) voltage pulses are injected into the boost converter on the gate G_{11} of the switch **34**. The PWM signal is programmed to make the shape of the averaged input current follow the shape of the input voltage and produce a high power factor. A boosted voltage across the capacitor **38** is then the input voltage of the DC/DC converter. The MOSFET switches **40** and **42** are programmed to turn on and turn off to give a regulated output voltage. These switches **40** and **42** are coupled to the switch **34** through the coupler chain, which couples the boost converter to the DC/DC converter. The discharge chain couples the coupler chain to the input of the DC/DC converter so that the discharge chain can discharge the capacitor **62** and the inductor **58** of the coupler chain.

The soft switch inductor **28** is coupled to switches **40** and **42**. The circuit as a whole operates the switches **34**, **40**, and **42** so as to soft switch each of the switches **34**, **40**, and **42** in the circuit. When the switch **42** turns off from its on state, current in the inductor **28** continues to flow and exchanges charge in capacitance across the switches **42** and **40**. The voltage across the switch **40** then falls to zero.

The switch **40** is programmed to turn on at zero voltage. When the voltage across the switch **40** falls, then the coupler chain of components is activated because the boost switch **34** is in the off state and the diode **36** is conducting. A resonant current flows through this chain and pulls current from the boost inductor **32**. Current through the diode **36** is reduced at a controlled rate and the turn off loss through the diode **36** is largely reduced. The resonant current will eventually become larger than the inductor current, which causes the diode **36** to turn off. The voltage across the switch **34** continues to fall under the influence of the resonant current in the coupler chain until it becomes substantially zero. Then, the switch **34** is programmed to turn on and the switching loss of the switch **34** is substantially reduced.

After the switch **34** remains on for the period of time needed by the boost converter, the switch **34** may be turned off regardless of the state of switches **40** and **42**. These switches **40** and **42** are complementary, such that when one switch is on the other switch is off. A small time gap between switches avoids shoot through. The time gap is very small and it is regarded that **40** and **42** operate asymmetrically. Thus, as the switch **34** is turned off, there are two cases of operability for switches **40** and **42**. A first case where the switch **40** is on and the switch **42** is off, and a second case where the switch **40** is off and the switch **42** is on.

In the first case, the capacitor **62** is settled to a voltage, when the switch **34** turns off, current is diverted to the capacitor **62** which acts like a snubber capacitor. Its voltage will eventually settle to the line voltage after the switch **34** has turned off.

In the second case, the capacitor **62** has discharged to near zero and does not interfere with the switching off of the switch **34**. Current flows through the inductor **32** and the boost diode **36** like the current would in prior art boost converter.

The states of switches **40** and **42** may also be changed at any time after the switch **34** has turned on at the beginning

of a duty cycle. Again there are two cases when the switch **40** turns off and the switch **42** turns on. The first case is where the switch **34** is still on and the second case is where the switch **34** is off. In both cases, the diode **60** prevents the initiation of resonant current through the inductor **58**. When the switch **40** is turned off, energy in the inductor **28** attempts to raise the voltage across the switch **40** and reduce the voltage across the switch **42**. Resonance in the coupler chain discharges the charge on the capacitor **62**. When the voltage across the switch has fallen to substantially zero it is programmed to turn on. Thus the switch **42** can turn on at a voltage substantially close to zero. The switch **42** remains on for its designated duty cycle. When the switch **42** is turned off, its current has changed direction, the voltage of the capacitor **62** is zero and the whole switching process will repeat.

With respect to drawing FIGS. **3A** to **3F**, the graphs of voltage and current during operation of the circuit of FIG. **2** are shown. FIGS. **3A** and **3B** show typical asymmetric gate driving pulses for the MOSFET switches **40** and **42**. The duty cycle of the control pulses are programmed to maintain a regulated DC output voltage at the converter output terminal across the resistor **68** shown in FIG. **2**. A small idling time period is inserted between the turn off and turn on of the switches **40** and **42**, as shown in the timing of the gate pulses to drive the switches in FIGS. **3A**, **3B** and **3C**. The switch **34** (FIG. **3A**) in the boost converter is turned on shortly after the switch **40** (FIG. **3B**) in the DC/DC converter has turned on but may turn off at any time in the cycle as explained above.

In FIGS. **3D** and **3E**, when the switch **42** turns off, current in the inductor **28** pulls the voltage at the drain terminals of the switches **40** and **34** at nodes **17** and **13** respectively, although these voltages may not fall at the same time and rate. Also, FIG. **3D** shows that when the switch **40** turns off, the current flowing in the inductor **28** will push the voltage at node **17** high and reduce the voltage across the switch **42**. The gate driving pulse will turn on the switch **42** when its drain source voltage has dropped to substantially zero. In FIG. **3F**, current through the diode **36** decreases in this transient period until it reaches zero. The switch **34** is programmed to turn on after its voltage is substantially zero. The same switching applies to the switch **40** which is programmed to turn on after its voltage is substantially zero. Thus, both switches **34** and **40** have zero voltage turn on. The diode **36** can then switch off with less reverse current. FIG. **3F** shows the current slope of the diode **36** has been limited, the reverse current can be controlled to be small which limits any significant losses. Thus, all switches **34**, **40** and **42** may turn on at zero voltage state.

With respect to FIG. **4**, a second embodiment of the present invention is shown. This second embodiment differs from the first embodiment in the placement of a small inductor **80** for resonance to provide zero voltage switching of the switch **34** in the boost converter. In the first embodiment, the small inductor **58** is placed in the coupling chain of components connecting the boost converter and the DC/DC converter. Nevertheless, this is not the only location to place the inductor. In this second embodiment, the inductor **80** is placed in series with the switch **34** in the boost converter. The switches **34**, **40** and **42** are controlled similar to the switches in FIG. **2**, and the output of the circuit is similar.

When the switch **34** switches off and the capacitor **62** has discharged to near zero, the energy stored in the inductor **80** is released through the diode **60** and flows through the coupling and discharging branches. The current through the

inductor **80** settles to zero and the inductor current through the inductor **32** will flow through the boost diode **36** similar to other boost converters.

A third embodiment of the present invention is shown in FIG. 5. This third embodiment differs from the first two embodiments in the placement of a small inductor **90** and a diode **92** for resonance to provide zero voltage switching of the switch in the boost converter. This third embodiment has the inductor **90** placed in between the input inductor **32** and the diode **36** of the boost converter. Another leg, which includes the diode **92**, is placed in the circuit between the inductor **90** and the diode **36**, and is then extended to the input terminal **30**. The switches **34** and **40** act substantially the same in this embodiment as they act in the first embodiment. When the voltage across the switch **40** falls, the voltage across the switch **34** falls simultaneously due to the coupling of the switches by the capacitor **62**.

The aforementioned embodiments use two small inductors, one coupled to the boost diode **36** and another one placed near the DC/DC converter primary side switches **40** and **42**, to obtain less voltage stress during turn off of the diode **36** and turn on of the switches **40** and **42**. Nevertheless, it is possible to combine these two small inductors into one inductor to further reduce the converter component count.

Turning now to FIG. 6, a circuit comprising a fourth embodiment of the present invention is shown. The embodiment is similar to the first embodiment, except the inductor **58** (FIG. 2) in the coupler chain and the soft switching inductor **28** (FIG. 2) are combined into a single inductor **94** coupled to the switches **40** and **42**. The inductor **94** provides soft turn off of diode **36** and also reduces voltage stress turn on of the switches **34**, **40**, and **42**.

When the switch **40** turns off, the current flowing in the series inductor **94** will continue to flow and discharge the stray capacitance across the drain source of the switch **40**. The voltage across the switch **42** will drop accordingly. The switch **40** then turns on when the voltage across the switch **40** drops to zero. The current flow direction of the inductor **90** then reverses and shunts the current flowing through the boost diode **36**. The inductor **94** also discharges the stray capacitance of the switch **34** via the path comprising the diode **60** and the energy limiting capacitor **62**. The voltage across the switch **34** then falls. When the voltage drops to essentially zero, then the switch **34** can be turned on with no switching loss. The rate of fall of current and the reverse recovery current during the turn off of the diode **36** is limited by the inductor **94**, therefore the turn off losses of the boost diode **36** can also be reduced.

Turning now to FIG. 7, a circuit comprising a fifth embodiment of the present invention is shown. This embodiment functions similar to the first embodiment, but the component count of this circuit is less. The capacitor **62** in the coupler chain and the discharge chain of the first embodiment are replaced by an active switch **100**, which couples the boost converter to the DC/DC converter. The coupler chain, including the diode **60**, the switch **100** and the inductor **94**, can softly turn off the boost diode **36** and reduce the turn on voltage of the switch **34** by selecting proper gate driving timing of the four switches **34**, **40**, **42**, and **100**. The inductor **94** provides soft turn off of the diode **36** and reduces voltage stress turn on for the switches **34**, **40**, and **42**.

In the previous embodiments, an energy limiting capacitor **62** limits energy transfer from the PFC boost converter side to the DC/DC converter side. Another diode **64** and an inductor **66** release the stored energy of the capacitor **62**

through the discharge chain. In the fifth embodiment, these components are replaced by the small active switch **100** which limits the energy transfer between the boost converter and the DC/DC converter during the switching transient by timing the gate signals of the switch **100** based upon the timing signals for the other gates **34**, **40**, and **42**.

With respect to FIGS. 8A to 8D, graphs of the driving waveforms for the switches of the circuit of FIG. 7 are shown. FIGS. 8A to 8C are similar to FIGS. 3A to 3C, which are the gate drives for the switches **40**, **42**, and **34**, respectively. As shown in FIG. 8D, the additional switch **100** is programmed to turn on before the switch **42** turns off. The switch **100** remains on throughout the transient during which the switches **34** and **40** switch on softly and the switch **42** turns off softly. Afterwards, this auxiliary switch **100** will then turn off and stop energy flow between the boost converter and the DC/DC converter side. This auxiliary switch **100** does not need to handle main power transfer, and it can be a very small MOSFET which operates for a short period of time.

The embodiments described herein are examples of structures having elements corresponding to the elements of the invention recited in the claims. This written description may enable those skilled in the art to make and use embodiments having alternative elements that likewise correspond to the elements of the invention recited in the claims. The intended scope of the invention thus includes other structures that do not differ from the literal language of the claims, and further includes other structures with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit with at least a first inductor, a first switch, a first rectifier and a first capacitor which is coupled to the input terminals and produce a voltage higher than the voltage at said input terminals;

means to couple the high voltage of said boost unit to a second switch and a third switch connected in series which produce a series of voltage pulses feeding into the primary side of a transformer through a second inductor and a second capacitor connected in series;

at least one secondary winding coupled to said transformer and this secondary winding is coupled to a set of rectifier and filter configuration for feeding power to an output load;

a first chain of components consisting of at least a third resonant inductor, a third resonant capacitor and a second diode, which is coupled to a node joining said first switch and first diode in said boost unit and another node joining said second and third switches;

a second chain of components consisting of at least a fourth resonant inductor and a third diode which is coupled to said third resonant capacitor in said first chain and a node attached to the high voltage source generated by said boost unit;

means to synchronize all the switches so that resonant current flows in said first and second chain such that the switches can be turned on and off while voltages across them are essentially zero.

2. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit with at least a first inductor, a first switch, a first rectifier diode and a first capacitor which is

coupled to said input terminals and produce a voltage higher than the voltage at said input terminals;

means to couple the high voltage of said boost unit to a second switch and a third switch connected in series which produce a series of voltage pulses feeding into the primary side of a transformer through a second series inductor and a second series capacitor;

at least one secondary winding coupled to said transformer and this secondary winding is coupled to a set of rectifier and filter configuration for feeding power to an output load;

a third inductor for resonance coupled between the anode of said first rectifier in said boost unit and said first switch in this said boost unit;

a first chain of components consisting of at least a third capacitor for resonance and a second diode, which is coupled to a node joining said first switch and said third resonant inductor and another node joining said second and third switches;

a second chain of components consisting of at least a fourth resonant inductor and a third diode which is coupled to said third resonant capacitor in said first chain and a node attached to the high voltage source generated by said boost unit;

means to synchronize all the switches so that resonant current flows in the first and second chain such that the switches can be turned on and off while voltages across them are essentially zero.

3. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit with at least a first inductor, a first switch, a first rectifier diode and a first capacitor which is coupled to the input terminals and produce a voltage higher than the voltage at said input terminals;

means to couple the high voltage of said boost unit to a second switch and a third switch connected in series which produce a series of voltage pulses feeding into the primary side of a transformer through a second inductor and a second capacitor connected in series;

at least one secondary winding coupled to said transformer and this secondary winding is coupled to a set of rectifier and filter configuration for feeding power to an output load;

a third inductor for resonance coupled between the anode of said first rectifier in said boost unit and said first switch in this said boost unit;

a first chain of components consisting of at least a third capacitor for resonance and a second diode, which is coupled to a node joining said first switch and said third resonant inductor in said boost unit and another node joining said second and third switches;

a second chain of components consisting of at least a fourth resonant inductor and a third diode which is coupled to said third resonant capacitor in said first chain and a node attached to the high voltage source generated by said boost unit;

a fourth diode with its anode coupled to said first switch and cathode coupled to anode of first rectifier diode;

means to synchronize all switches so that resonant current flows in said first and second chain such that all switches can be turned on and off while voltages across them are essentially zero.

4. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit with at least a first inductor, a first switch, a first rectifier diode and a first capacitor which is coupled to the input terminals and produce a voltage higher than the voltage at said input terminals;

means to couple the high voltage of said boost unit to a second switch and a third switch connected in series which produce a series of voltage pulses feeding into the primary side of a transformer through a second inductor and a second capacitor connected in series;

at least one secondary winding coupled to said transformer and this secondary winding is coupled to a set of rectifier and filter configuration for feeding power to an output load;

a first chain of components consisting of at least a third capacitor for resonance and a second diode, which is coupled to a node joining said first switch and said first diode in said boost unit and another node joining said second capacitor and said second inductor in the primary circuit of said transformer;

a second chain of components consisting of at least a third resonant inductor and a third diode which is coupled to said third capacitor in said first chain and a node attached to the high voltage source generated by said boost unit;

means to synchronize all the switches so that resonant current flows in the first and second chain such that the switches can be turned on and off while voltages across them are essentially zero.

5. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit with at least a first inductor, a first switch, a first rectifier diode and a first capacitor which is coupled to the input terminals and produce a voltage higher than the voltage at said input terminals;

means to couple the high voltage of said boost unit to a second switch and a third switch connected in series which produce a series of voltage pulses feeding into the primary side of a transformer through a second inductor and a second capacitor connected in series;

at least one secondary winding coupled to said transformer and this secondary winding is coupled to a set of rectifier and filter configuration for feeding power to an output load;

a first chain of components consisting of at least a fourth switch and a second diode, which is coupled to a node joining said first switch and said first diode in said boost unit and another node joining said second capacitor and said second inductor in the primary circuit of said transformer;

means to synchronize all switches so that resonant current flows in the first and second chain such that the switches can be turned on and off while voltages across them are essentially zero.

6. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit coupled to the input terminals and generating a voltage higher than the voltage at the input terminals;

a DC/DC converter coupled to the boost unit and comprising series switches coupled to the primary side of a

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transformer through a series inductor and capacitor, and further including a secondary winding coupled to the transformer and coupled to a rectifier and filter configuration;

a coupler chain coupling the boost unit to the DC/DC converter;

a discharge chain coupled to the coupler chain and coupled to a high voltage source generated by the boost unit; and

control pulses synchronizing the series switches so that a resonant current flows in the coupler chain and the discharge chain such that the switches can be turned on and off while voltages across the switches are substantially zero.

7. The power converter of claim 6, wherein said coupler chain comprises an inductor, a diode, and a capacitor.

8. The power converter of claim 7, wherein the discharge chain comprises a diode and an inductor.

9. The power converter of claim 7, wherein the series inductor of the DC/DC converter is also the inductor of the coupler chain.

10. The power converter of claim 6, wherein the coupler chain comprises a capacitor and a diode.

11. The power converter of claim 10, wherein a diode is coupled between one of the input terminals and the boost unit.

12. The power converter of claim 6, wherein the output of the transformer is coupled to a rectifier.

13. The power converter of claim 12, wherein the rectifier is coupled to a filter.

14. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit comprising a first inductor, a first switch, a first rectifier diode and a first capacitor coupled to the input terminals and producing a voltage higher than the voltage at said input terminals;

means to couple the high voltage of the boost unit to a second switch and a third switch connected in series, the second and third switches feeding a series of voltage pulses into the primary side of a transformer through a second series inductor and a second series capacitor;

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a secondary winding coupled to the transformer and coupled to a rectifier and filter for feeding power to an output load;

a third inductor coupled between the anode of the first rectifier in the boost unit and the first switch in the boost unit, the third inductor configured to resonate a current flow;

a first chain of components comprising a third capacitor and a second diode coupled to a node joining the first switch and the third inductor;

a second chain of components comprising a fourth inductor and a third diode coupled to the third capacitor in the first chain, the second chain being coupled to the high voltage source generated by the boost unit; and

means to synchronize the switches so that the resonant current flows in the first and second chain such that the switches can be turned on and off while voltages across the switches are substantially close to zero.

15. A power converter apparatus, comprising:

a pair of input terminals for connection to a pulsating DC source;

a boost unit coupled to the input terminals and generating a voltage higher than the voltage at the input terminals;

a DC/DC converter coupled to the boost unit and comprising series switches coupled to the primary side of a transformer through a series inductor and capacitor, and further including a secondary winding coupled to the transformer and coupled to a rectifier and filter configuration;

a coupler chain coupling the boost unit to the DC/DC converter; and

control pulses synchronizing the series switches so that a resonant current flows in the coupler chain and the discharge chain such that the switches can be turned on and off while voltages across the switches are substantially zero.

16. The power converter of claim 15, wherein the coupler chain comprises a diode and a switch.

17. The power converter of claim 15, wherein the output of the transformer is coupled to a rectifier.

18. The power converter of claim 17, wherein the rectifier is coupled to a filter.

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